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**IS : 9001 ( Part IV ) - 1979**

**( Reaffirmed 2004 )**

# *Indian Standard*

# GUIDANCE FOR ENVIRONMENTAL TESTING

## PART IV DAMP HEAT TESTS

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*January* 1980

# *Indian Standard*

# GUIDANCE FOR ENVIRONMENTAL TESTING

## PART IV DAMP HEAT TESTS

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# *Indian Standard*

# GUIDANCE FOR ENVIRONMENTAL TESTING

## PART IV DAMP HEAT TESTS

## 0. FOREWORD

**0.1** This Indian Standard ( Part IV ) was adopted by the Indian Standards Institution on 18 September 1979, after the draft finalized by the Environmental Testing Procedures Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

**0.2** The damp heat tests are intended to determine the ability of electronic and electrical items to withstand the stresses occurring in a climate of high relative humidity, with or without condensation, and in some cases also of higher temperatures with special regard to variations of electrical and mechanical characteristics.

**0.2.1** The damp heat test may also be applied to check the resistance of the item to some forms of corrosion attack.

**0.3** This standard should be used together with those parts of IS : 9000* which contain damp heat tests as given below:

a) Part IV Damp heat ( steady state ) test,
b) Part V Damp heat ( cyclic ) test, and
c) Part VI Composite temperature/humidity cyclic test.

**0.4** This standard is intended to give guidance on physical processes and its effects which lead to failure of item under humidity conditions and necessary information for the selection of appropriate damp heat tests or test severities for a particular item and possibility for a given kind of application.

**0.4.1** In general, damp heat ( cyclic ) test requires more expensive test equipment or more supervising personnel than damp heat ( steady state ) test.

**0.5** This standard is largely based on Doc : 50B ( Central Office ) 205 'Draft—Revision of Publication 68-2-28: Guidance for damp heat tests' issued by the International Electrotechnical Commission.

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*Basic environmental testing procedures for electronic and electrical items.

## 1. SCOPE

**1.1** This standard ( Part IV ) deals with the guidance for damp heat tests on electronic and electrical items and on the selection of the appropriate tests and test severities for a particular item and for a given kind of application.

## 2. TERMINOLOGY

**2.0** For the purpose of this standard, the following definitions, in addition to those covered in IS : 9000 ( Part I )-1977*, shall apply.

**2.1 Condensation** — The precipitation of water vapour on a surface when the surface temperature is lower than the dew point temperature of the ambient air. The water is thereby transformed from the vapour to the liquid state of aggregation.

**2.2 Adsorption** — The adherence of water molecules to a surface when the surface temperature is higher than the dew point temperature.

**2.3 Absorption** — The accumulation of water molecules within a material.

**2.4 Diffusion** — The transportation of water vapours through a material produced by a partial pressure difference.

NOTE — Diffusion results in a balance of partial pressures whilst flow ( such as, through leaks, when the dimensions of such leaks are great enough to provide viscous or laminar flow ) always results in the balance of the total pressures.

## 3. ENVIRONMENTAL INFLUENCE OF DAMP HEAT

### 3.1 General

**3.1.1** The temperature and relative humidity of the air in varying combinations are climatic factors which always act upon a product during storage, transport and operation.

**3.1.2** Meteorological measurements made over many years have shown that a relative humidity greater than or equal to 95 percent combined with a temperature over 30°C does not occur in free air conditions over long periods, except in regions with extreme climates. In dwelling rooms and workshops, temperatures of over 30°C may occur but in most cases are combined with a lower relative humidity than in the open air.

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*Basic environmental testing procedures for electronic and electrical items: Part I General.

**3.1.3** Special conditions exist in certain wet rooms in the chemical industry, metallurgical plants, mines, electroplating plants, laundries, etc, where the temperature can reach as much as 45°C combined with a relative humidity of 100 percent over long periods.

However, it is possible that certain equipment placed under particular conditions may be subjected to relative humidities of more than 95 percent at higher temperatures. In particular, this may happen when the equipment is placed in enclosures, such as, vehicles, tents or aircraft cockpits, since this can result in intense heating through solar radiation while, because of inadequate ventilation, any humidity which may be developed will be retained permanently within the interior.

**3.1.4** In rooms having several heat sources, temperatures and relative humidities may differ in different parts of the room.

**3.1.5** Atmospheric pollution which is found to a large extent in a number of places can intensify the effects of a damp climate on products. Attention is drawn to this fact because of its general importance, although pollutants are not contained in the atmospheres used for damp heat testing. If the effects of pollutants are to be investigated, a suitable test, for example, corrosive atmospheres or mould growth, should be used.

## 4. PROCEDURES FOR PRODUCTION OF HUMIDITY

**4.1 General** — There are a great number of humidity test chambers available, equipped with different systems of generation of humidity and of humidity control. In the subsequent clauses only the principal methods of generation of humidity are described.

**4.2 Water Spraying** — De-ionized water is atomized to very fine particles. The aerosol produced in this way moistens the air stream before entering into the working space of the chamber, the greater part of the droplets evaporating on the way. Direct injection into the working space should be avoided.

This simple system gives rapid humidification and needs little maintenance. In particular, when using direct injection, small amounts of aerosol may remain in the working space; rapid changes of humidity may be difficult to control ( overshoot ).

**4.3 Injection of Water Vapour** — Hot water vapour is blown into the working space of the chamber.

This system gives rapid humidification and it is easy to control the quantity of vapour ( steam valve ). Condensation on cooler parts of the chamber may occur. The heat input may necessitate additional cooling with possible de-humidification effects.

### 4.4 Volatilization

**4.4.1** *Bubbling-Through Type* — Air is blown through a vessel containing water thus becoming saturated with vapour.

This system is simple. At a fixed air flow the humidity is easily controlled by changing the water temperature. If an increase of humidification is produced by increasing the water temperature, this may cause a temperature rise in the working space and introduce a time lag due to the thermal capacity of the water. The bubbles may produce a small amount of aerosol when bursting.

**4.4.2** *Surface Volatilization* — The air is humidified by passing it over a large surface area of water. Different methods are used, for example, repeated air flow over standing water, water-jet scrubbing over a vertical surface with the air stream in counter current.

In this system the generation of aerosols is minimized. The humidity is easily controlled by changing the water temperature. Due to the thermal capacity of the water a time lag in the change of humidity may occur.

**4.5 Aqueous Solutions** — A defined relative humidity is generated over standardized aqueous solutions in small sealed chambers at constant temperature. Proved methods with glycerine or salt solutions are described in IS : 8145-1976*.

This is a simple and reliable system. In general it is not appropriate for heat dissipating items or for items absorbing large quantities of moisture.

Salt particles may be deposited on the surface of the test item in poorly designed chambers. In some cases, for example with ammonium salts, there may be hazards to health and they may give rise to stress corrosion on copper alloys.

## 5. PHYSICAL APPEARANCE OF HUMIDITY ( *See* APPENDIX A )

### 5.1 Condensation

**5.1.1** The dew point temperature depends on the content of water vapour in the air. A direct relationship exists between dew point, absolute humidity and vapour pressure.

**5.1.2** Condensation occurs on an item when introduced into a test chamber, if its surface temperature is lower than the dew point temperature of the chamber air.

---

*Specification for test chambers of non-injection type for constant relative humidity.

**5.1.3** It may, therefore, be necessary to pre-heat the item if condensation is not desired.

**5.1.4** When condensation is desired on the item during the conditioning period the temperature and the water content of the air should rise so fast that a difference between dew point temperature and surface temperature is achieved.

**5.1.5** If the item has a low thermal time constant, condensation occurs only if the temperature of the air increases very rapidly, or if the relative humidity is very close to 100 percent. With the rate of temperature-rise prescribed for damp heat ( cyclic ) tests condensation may not occur on very small items.

**5.1.6** Small amounts of condensation may be found on the inner surface of casings subsequent to a fall in ambient temperature. In general, condensation may be detected unambiguously only by visual inspection. This is, however, not always possible, especially with small objects having a rough surface.

**5.2 Adsorption** — The amount of humidity that may adhere to the surface depends on the type of material, its surface structure and the vapour pressure. A separate evaluation of the adsorption effects is not easy because the effects of the simultaneously occurring absorption are usually more evident.

**5.3 Absorption** — The quantity of moisture which will be absorbed, depends largely on the water content of the ambient air. The absorbing process proceeds steadily until equilibrium is established. The speed of penetration of the water molecules rises with the temperature ( *see* **6.1** ).

**5.4 Diffusion** — An example of diffusion which is frequently found in electrical engineering is the penetration of water vapour through encapsulations of organic material, for example, into a capacitor or semiconductor or through the sealing compound into the casing.

## 6. ACCELERATION

### 6.1 General

**6.1.1** The aim a of test is to obtain as far as possible the same changes of characteristics as would occur in the normal service environment. In general, an acceleration is aimed at so that such tests may be made in a shorter time as compared with normal conditions of use. It should be emphasized, however, that different failure mechanisms may occur under severe conditions than would occur under less severe conditions.

**6.1.2** The severity of the test shall be chosen taking into account the limiting conditions of service and storage for which an item is constructed.

**6.1.3** While the time required for condensation and adsorption processes is in general rather short, much longer periods of time — up to several thousand hours — may be needed for absorption and diffusion processes until the equilibrium state is reached.

**6.1.4** When the relationship between penetration speed and temperature is known, acceleration of a damp heat test may be achieved by using a higher temperature.

**6.1.5** The cycling of temperature as applied in the damp heat ( cyclic ) tests has in general no accelerating effect on the absorption and diffusion processes. In view of the fact that the speed of penetration of water vapour increases with rising temperature, the absorption will proceed slower with damp heat ( cyclic ) tests if the effective average value of the two temperature levels is lower than the conditioning temperature of damp heat ( steady state ) test.

### 6.2 Acceleration Factor

**6.2.1** It is not possible to give a generally valid acceleration factor for damp heat tests. If it is desired to know the acceleration factor it can only be determined empirically for each particular product.

**6.2.2** For comparative tests, a high degree of acceleration may be useful and admissible if the failure mechanism does not change for the different items.

## 7. COMPARISON OF STEADY STATE, CYCLIC AND COMPOSITE TESTS

### 7.1 Damp Heat ( Steady State )

**7.1.1** The steady state tests should always be used where adsorption or absorption play the main part. When diffusion but not breathing is involved either the steady state or the cyclic test shall be applied depending on the type of item and its application.

**7.1.2** In many cases damp heat ( steady state ) test is applied to determine whether the required electrical characteristics of the dielectric are maintained in humid atmosphere or whether an insulating encapsulation may guarantee sufficient protection.

**7.1.3** For a number of items the stresses produced by a steady state test are very similar to those produced by a cyclic test ( *see* **6.1** and **7.2** ). In these cases economic reasons should prevail when choosing the appropriate test.

**7.1.4** Expenses for test equipment and personnel for a steady state test are considerably lower than for a cyclic test. Especially the expenses for long term tests over several hundreds up to many thousands of hours may be kept within reasonable limits only by using a steady state test.

### 7.2 Damp Heat ( Cyclic )

**7.2.1** In general, the damp heat ( cyclic ) test requires more expensive test equipment.

**7.2.2** Cyclic tests shall be applied in all the cases where condensation is important or when the penetration of vapour will be accelerated by the breathing effect. Breathing effect in this context is the exchange of air between a hollow space and its surroundings, produced by changes of temperature.

**7.2.3** When leaks are to be detected in items including hollow spaces, sealing test should preferably be used.

**7.2.4** For the testing of solid items ( without hollow spaces ) damp heat ( steady state ) test will normally be the appropriate method ( *see* **7.1** ). However, when condensation is important, damp heat ( cyclic ) test has to be applied.

**7.2.5** When fissures in an encapsulation or in a seal are to be expanded by thermal stress, this may often be done more effectively by an appropriate test sequence or a composite test than with a damp heat ( cyclic ) test.

### 7.3 Composite Temperature/Humidity Cyclic

**7.3.1** A composite temperature/humidity cyclic test ( moisture resistance test ) is designed to reveal defects in test items caused by breathing as distinct from the absorption of moisture. This test differs from other cyclic damp heat tests in that it derives its increased severity from:

a) the greater number of temperature variations or pumping action in a given time;
b) the greater cyclic temperature range;
c) the higher cyclic rate of change of temperature;
d) The inclusion of a number of excursions to sub-zero temperatures; and
e) the inclusion of vibration conditioning, if required.

**7.3.1.1** The accelerated breathing and the effect of the freezing of trapped water in cracks and fissures are the essential features of this composite test. It is emphasized, however, that the freezing effect will occur only if the fissure dimensions are large enough to allow the penetration of a coherent mass of water, as is normally the case in fissures between seals and metal assemblies or between seals and wire terminations.

**7.3.1.2** The degree of condensation will depend mainly upon the thermal time constant of the surface of the test items and may be negligible for very small items but copious for large items.

**7.3.1.3** The breathing effect will be more apparent on items which contain relatively large air-filled or gas-filled voids but again the severity of the test will depend to some extent on the thermal characteristics of the items.

**7.3.2** It is recommended that this test procedure should be limited to component type of items when the construction of the items suggests a breathing type of damp heat test combined with icing and where the thermal characteristics are compatible with rates of change of temperature.

**7.3.2.1** As in other damp heat tests, a polarizing voltage or electrical loading may be applied to the items. In the case of electrical loading, the loading should be such that the temperature rise of the items does not unduly affect the chamber conditions.

**7.3.2.2** It is to be noted that composite temperature/humidity cyclic test should not be considered to be interchangeable with, or an alternative to, either steady state or other cyclic damp heat tests, but the choice of test procedure should be made with due regard for the physical and thermal characteristics of the test items and the types of failure mechanisms which are significant for each particular case.

### 7.4 Climatic Sequence and Composite Temperature/Humidity Cyclic Test

**7.4.1** A proven method to determine the tightness of joints or to detect hairline cracks is to apply one or more temperature cycles. In most cases, it is, however, not necessary to combine, the temperature change with the humid atmosphere, that is, to produce the two conditions simultaneously.

**7.4.2** The desired effect may be made more stringent when the change of temperature test is applied, followed by the climatic sequence. The effect will also be enhanced if the humidity test is immediately followed by cold test. The large temperature differences with change of temperature test produces a much greater thermal stress than damp heat ( cyclic ) test where the rate of change of temperature is rather slow.

**7.4.3** A composite test as specified in IS : 9000 ( Part VI )-1978* consisting of several damp heat cycles and cold sub-cycles is recommended when items composed of different materials and including joints, especially items including cemented glass joints, are to be tested. Such test differs from other cyclic damp heat tests in that it derives its added effectiveness from a greater number of temperature variations in a given time, a higher upper temperature, and the addition of a number of excursions to sub-zero temperatures.

**7.4.3.1** The accelerated breathing and the effect of the freezing of trapped water in cracks or fissures are the essential effect of the composite test.

**7.4.3.2** The introduction of cold cycles between the humidity cycles is intended to freeze water which may have been retained in any defects and by expansion due to freezing, to convert such defects into faults more rapidly than would occur during normal life.

**7.4.3.3** It is emphasized however that the freezing effect will occur only if the fissure dimensions are large enough to allow the penetration of a coherent mass of water as is normally the case in fissures between seals and metal assemblies or between seals and wire terminations.

**7.4.3.4** For small hairline cracks or porous materials, for example, in plastic encapsulation, the absorption effect will prevail and a damp heat ( steady state ) test is to be preferred for investigation of these effects.

**7.4.3.5** It is emphasized that the composite test is more expensive to carry out than the other damp heat tests and should only be used when the deterioration effects may not be reproduced by the simpler damp heat ( steady state ) test or damp heat ( cyclic ) test.

## 8. INFLUENCE OF TEST ENVIRONMENT ON ITEMS ( *see* APPENDIX A )

**8.1 Change of Physical Characteristics** — In a humid atmosphere mechanical and optical characteristics of materials may change.

*Examples*:

> Dimensional changes by swelling, variation of surface characteristics, such as the coefficient of friction, change of strength, etc.

To determine such changes of characteristics, it depends on the application whether a steady state or a cyclic test is appropriate, and whether or not condensation should be required.

---

*Basic environmental testing procedures for electronic and electrical items: Part VI Composite temperature/humidity cyclic test.

## 8.2 Change of Electrical Characteristics

**8.2.1** *With Surface Moisture* — If the surface of an insulating material is affected by condensation or by a certain amount of absorbed humidity certain electrical characteristics may change, for example, decrease of surface resistance, increase of loss angle. Moreover, leakage currents may occur.

In general, damp heat ( cyclic ) test is applied in these cases. If, for a given application, condensation is excluded, damp heat ( steady state ) test may be used as well.

In certain cases the items have to be switched on, loaded or measured during conditioning. In general, changes of electrical characteristics due to surface moisture become evident after some minutes.

**8.2.2** *With Penetrated Moisture* — The moisture absorbed by an insulating material may produce a variation of a number of electrical characteristics, for example, decrease of dielectric strength, decrease of insulation resistance, increase of loss angle, increase of capacitance.

Since the absorption and diffusion processes occur over long periods of time and the equilibrium state is reached only after some hundreds or even thousands of hours, long conditioning times shall be chosen accordingly. The extrapolation of test results is only possible if the time dependency is known. As an example, plastic encapsulation which appears satisfactory after 56 days of exposure to damp heat ( steady state ) test may have deteriorated after six months due to the absorption or diffusion of too high a quantity of moisture.

The evaluation of the influence of absorbed moisture may become problematic when the functional parts in the encapsulation are additionally protected against humidity, for example, by the passivation of semiconductors, by enclosing drying agents, etc.

**8.3 Corrosion** — Most kinds of corrosion can occur only when a sufficient amount of humidity is available. With increasing humidity or temperature the corroding effect is accelerated; the most severe deterioration by corrosion will in general occur when there is frequent condensation with re-evaporation.

In general, damp heat tests should not be used for determination of corrosion effects but when foreign substances are deposited on metallic surfaces, for example, flux residues, other residues of manufacturing processes, dirt, finger prints, etc, these may produce or promote corrosion in the presence of humidity.

Joints between different metals or between metal and a non-metallic material may be a source of corrosion when condensation or a high relative humidity is present without pollutants.

# APPENDIX A

## ( *Clauses* 5 *and* 8 )

## HUMIDITY EFFECTS DIAGRAM

### A-1. GENERAL

**A-1.1** Figure 1 shows the basic physical processes involved in humidity testing and shows the links between these processes, the constructional features or the materials of the item, and the effects of the test.

Where applicable or where there is felt to be sufficient knowledge at present available to justify it, symbols corresponding to the various test parameters listed below have been inserted in the various ' boxes '.

| | |
|---|---|
| Time ( total duration of test ) | t |
| Temperature | $\theta$ |
| Change of temperature | $\Delta\theta$ |
| Rate of change of temperature | $d\theta/dt$ |
| Relative humidity | r.h. |
| Absolute humidity | a.h. |
| Degree of impurities present in the test atmosphere | Pu. |

### A-2. EXPLANATORY NOTES

**A-2.1 Method of Entry** — The box labelled ' Breathing ' in the second line of the diagram is intended to indicate any process by which moisture penetrates an imperfect seal such as coatings, containers, hoses, tubes, etc.

For items in which the outer surface forms part of the dielectric or other functional material of the item, this ' box ' may not be applicable and the moisture would then attack the item directly by one or both of the moisture would then attack the item directly by one or both of the basic mechanisms indicated on the third line.

**A-2.2 Physical Processes ( *see* 5 )**

**A-2.3 Effects ( *see* 8 )**

**A-2.4 Examples of Effects**

**A-2.4.1** The last line lists typical examples of the effects ( *see* **8** ) but it should not be assumed that the examples quoted are necessarily the only ones which may result from these physical processes ( *see* **5** ).

The ' boxes ' in this line should not be considered as being completely separate, since interaction between the various effects is both possible and probable.

This is indicated in the fourth box from the left, where chemical reactions between materials and moisture are indicated as possibly leading to changes in volume resistivity, loss angle, etc; and whilst this is one of the more obvious interactions there are undoubtedly many others.

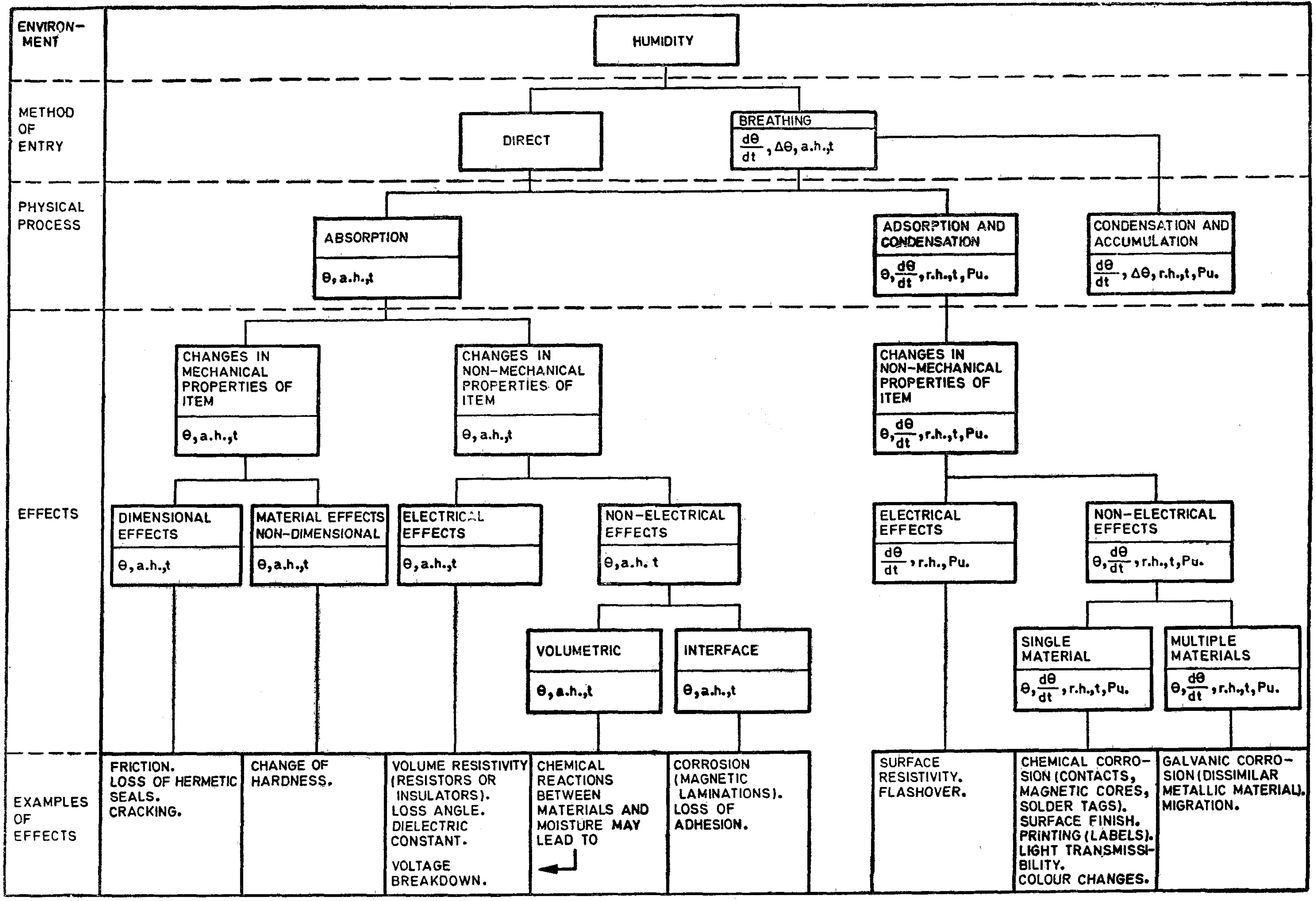
ENVIRONMENT
METHOD OF ENTRY
PHYSICAL PROCESS
EFFECTS
EXAMPLES OF EFFECTS
HUMIDITY
DIRECT
BREATHING
$\frac{d\theta}{dt}$, $\Delta\theta$, a.h., t
ABSORPTION
$\theta$, a.h., t
ADSORPTION AND CONDENSATION
$\theta$, $\frac{d\theta}{dt}$, r.h., t, Pu.
CONDENSATION AND ACCUMULATION
$\frac{d\theta}{dt}$, $\Delta\theta$, r.h., t, Pu.
CHANGES IN MECHANICAL PROPERTIES OF ITEM
$\theta$, a.h., t
CHANGES IN NON-MECHANICAL PROPERTIES OF ITEM
$\theta$, a.h., t
CHANGES IN NON-MECHANICAL PROPERTIES OF ITEM
$\theta$, $\frac{d\theta}{dt}$, r.h., t, Pu.
DIMENSIONAL EFFECTS
$\theta$, a.h., t
MATERIAL EFFECTS NON-DIMENSIONAL
$\theta$, a.h., t
ELECTRICAL EFFECTS
$\theta$, a.h., t
NON-ELECTRICAL EFFECTS
$\theta$, a.h. t
ELECTRICAL EFFECTS
$\frac{d\theta}{dt}$, r.h., Pu.
NON-ELECTRICAL EFFECTS
$\theta$, $\frac{d\theta}{dt}$, r.h., t, Pu.
VOLUMETRIC
$\theta$, a.h., t
INTERFACE
$\theta$, a.h., t
SINGLE MATERIAL
$\theta$, $\frac{d\theta}{dt}$, r.h., t, Pu.
MULTIPLE MATERIALS
$\theta$, $\frac{d\theta}{dt}$, r.h., t, Pu.
FRICTION. LOSS OF HERMETIC SEALS. CRACKING.
CHANGE OF HARDNESS.
VOLUME RESISTIVITY (RESISTORS OR INSULATORS). LOSS ANGLE. DIELECTRIC CONSTANT.
VOLTAGE BREAKDOWN.
CHEMICAL REACTIONS BETWEEN MATERIALS AND MOISTURE MAY LEAD TO ←
CORROSION (MAGNETIC LAMINATIONS). LOSS OF ADHESION.
SURFACE RESISTIVITY. FLASHOVER.
CHEMICAL CORROSION (CONTACTS, MAGNETIC CORES, SOLDER TAGS). SURFACE FINISH. PRINTING (LABELS). LIGHT TRANSMISSIBILITY. COLOUR CHANGES.
GALVANIC CORROSION (DISSIMILAR METALLIC MATERIAL). MIGRATION.

FIG. 1 HUMIDITY EFFECTS DIAGRAM